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CITY AND GUILDS OF LONDON INSTITUTE

Telecommunications Technicians (New) Scheme

The following questions are from examination papers set for the City and Guilds of London Institute's (CGLI's) new 271 Telecommunications Technicians Scheme, and are reproduced with the permission of the CGLI. The answers given have been prepared by independent authors. Answers to some questions are omitted because of insufficient space. Students studying BTEC courses at the higher level may find that these questions are useful for revision.

CGLI: SWITCHING T4 OPTION (1985)

Students were required to answer six questions. The total time allowed was three hours. Students are advised to read the notes above

Q1 (a) Comparing a large group of trunks with a small group, explain

- (i) with the aid of a graph why their efficiency is greater, and
- (ii) why they are less able to withstand traffic overloads during the busy hour. (8 marks)

(b) Describe in general terms how traffic tables are used for groups of trunks connected to

- (i) a level of a 200-outlet Strowger group selector, and
- (ii) a uniselector.

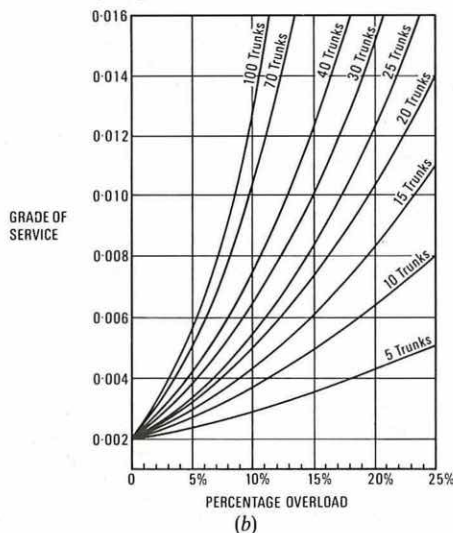
Include a sketch which shows how the various items of information are presented on the traffic table. (8 marks)

(c) Explain the condition that makes it necessary to provide a grading for a group of trunks. (4 marks)

A1 (a) (i) Sketch (a) indicates the average traffic per trunk for full-availability groups of various sizes. For a small group of trunks, the total traffic carried is low for the standard grade of service of one lost call in 500 (0.002). For example, a group of five trunks can carry 0.9 erlang, with an average of 0.18 erlang per trunk. For a large group of trunks, the total traffic carried is comparatively higher than the smaller group. For example, a group of 20 trunks can carry 10 erlangs,

with an average of 0.5 erlang per trunk. This indicates that a large group of trunks is more efficient at carrying traffic than smaller groups of trunks.

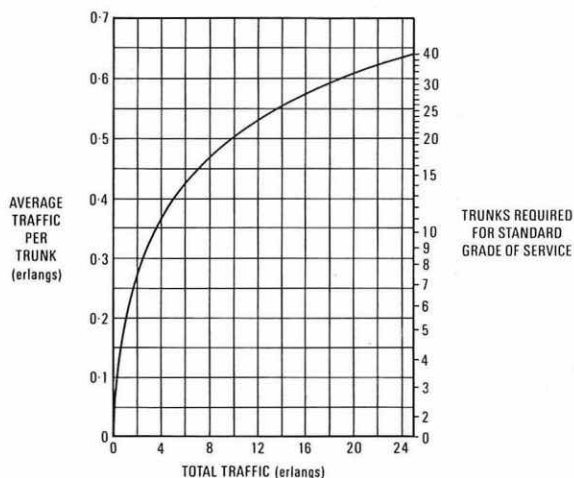
(ii) Sketch (b) indicates the effect of traffic overload on groups of trunks of various sizes. It can be seen that, for small groups, the effect of overload on the grade of service is much less than the effect on large groups. For example, a 10% overload on a group of five trunks causes the grade of service to fall to 0.003, whereas on a group of 20 trunks the grade of service falls to 0.005. The reason for this is that, with a large group of trunks, the first-choice trunks are more efficiently loaded and are less likely to withstand a temporary overload than the similar outlets of a smaller group.



(b) Traffic tables are available to be used for various groups of trunks. For full-availability conditions, tables indicate traffic offered to each trunk for various values of total traffic, traffic carried by each trunk for various values of total traffic, and total traffic carried by various groups of trunks for certain values of grade of service.

- (i) For a 200-outlet Strowger group selector, a level has 20 outlets.
- (ii) A uniselector normally has 24 outlets.

Tables 1, 2, and 3 indicate the format of the information presented in the traffic tables.



(a)

Table 1

Contact Number	Traffic offered to each contact when total traffic is:					
	1	2	3	4	5	etc.
1	...	...	...	...	...	
2	...	...	...	...	...	
3	...	...	...	...	...	
etc.	...	...	...	...	...	

↑ ↑ ↑ ↑ ↑
Values of traffic in erlangs

Table 2

Contact Number	Traffic carried by each contact when total traffic is:					
	1	2	3	4	5	etc.
1	...	...	...	...	...	
2	...	...	...	...	...	
3	...	...	...	...	...	
etc.	...	...	...	...	...	

↑ ↑ ↑ ↑ ↑
Values of traffic in erlangs

Table 3

Number of trunks	Capacity in erlangs for grade of service of:			
	0.005	0.002 (standard)	0.001	etc.
1	...	...	...	
2	...	...	...	
3	...	...	...	
etc.	...	...	...	

↑ ↑ ↑
Values of traffic in erlangs

For a 200-outlet group selector, the values up to 20 on the left-hand column of the tables are used and, for a uniselector, values up to 24 are used.

[Tutorial Note: Students would not be expected to reproduce actual traffic tables.]

(c) The condition that makes it necessary to provide a grading for a group of trunks is known as *limited availability*; this is where the number of switches at one stage exceeds the number of outlets on a level of the switch at the preceding stage. In effect, switches at one stage do not have access to all the switches at the next stage.

Q2 (a) State the basic reason for providing EACH of the following items of equipment in automatic telephone exchanges:

- (i) automatic traffic recorder,
- (ii) automatic traffic equipment, and
- (iii) fault recorders. (6 marks)

(b) For EACH of the items of equipment in (a) explain briefly

- (i) the principle of operation, and
- (ii) how the information that they provide is used to improve, where necessary, the performance of the exchange. (14 marks)

A2 (a) (i) The automatic traffic recorder is provided in automatic telephone exchanges to assess the traffic carried by the exchange. Originally, manual switch counts were made, but these were laborious and required large numbers of staff. The automatic traffic recorder enables the count to be taken without the need for staff and at more frequent intervals, thus enabling a much more accurate record to be achieved.

(ii) Artificial traffic equipment is used in automatic telephone exchanges to locate faulty plant. The equipment can also be used to obtain a quality-of-service measurement to supplement the existing fault statistics. The equipment has an advantage over automatic routers because it can test the entire switching path through an exchange, including interstage wiring, whereas routers can test only individual switches.

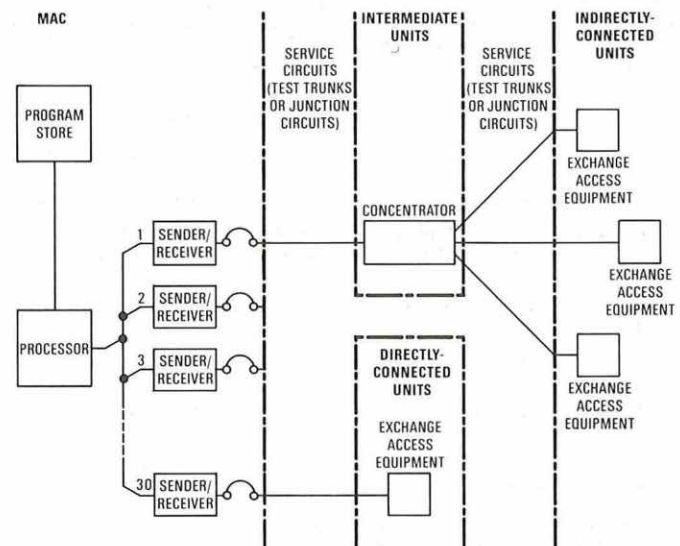
[Tutorial Note: It is assumed that there was a typographical error in the original question paper in referring to 'automatic' traffic equipment.]

(iii) Fault recorders are used to record automatically details of equipment found faulty.

(b) (i) The automatic traffic recorder measures telephone traffic by scanning specific traffic-carrying devices at regular intervals and recording whether they are FREE or BUSY. The number of times a device was found to be busy divided by the number of times a device was scanned gives an estimate of the proportion of time for which it is occupied, which is equal to the traffic carried in erlangs. The total traffic on a group of devices is obtained by dividing the total number of 'busies' by the number of complete scanning cycles. In practice, speech-carrying equipment is scanned at 3 min intervals, whereas common equipment (for example, registers) is scanned at 12 or 18 s intervals. Originally, traffic recorders were of electromechanical design, with the recorded 'busies' and numbers of scans recorded on meters; however, more modern electronic equipment is being introduced which uses micro-processor control with the recorded traffic data automatically stored on a magnetic-tape cartridge for off-line processing and analysis at a centrally provided computer. This modern method has the advantage that specific programmes of traffic recording can be recorded on the cartridge tape by specialist staff at the computer site for input to traffic recorders, and traffic can be gathered over longer periods.

Measurement and analysis centres (MACs) are a type of artificial traffic equipment, and they provide the facility to measure the quality of service given by the telephone switching network. The equipment generates a series of test calls under the control of miniprocessors and the performance is monitored. The MAC can record the outcome of the test calls; for example, calls that are satisfactory or fail for various reasons.

The MAC equipment is provided on an area basis and is connected to exchanges as indicated in sketch (a).



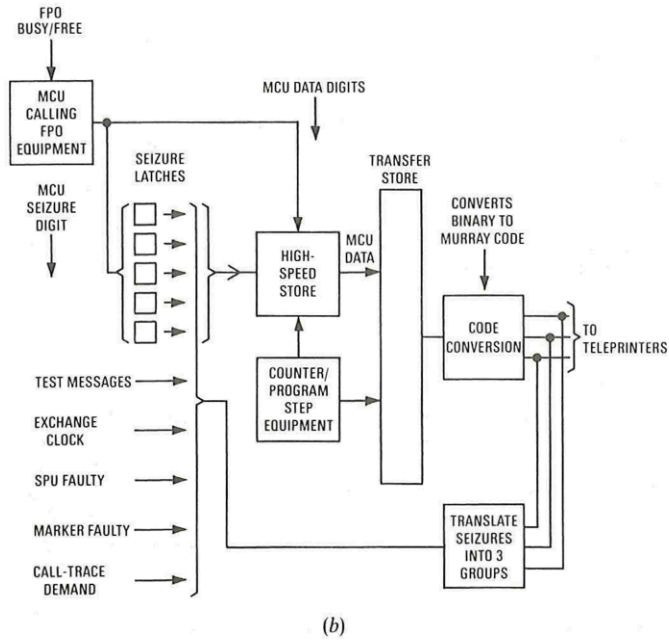
(a)

Service circuits connect the MAC to the exchange access equipment, via concentrators where appropriate, and are usually located at the group switching centre. Each exchange unit to be measured is connected by exchange access equipment, enabling test traffic to be connected to customers' line circuits, register-access relay-sets or incoming trunk selectors (or the equivalent in crossbar, reed-electronic or digital switching systems).

The fault recorder equipment for the TXE4 electronic exchange system consists of fault print-out (FPO) equipment and associated teleprinters. The information to the FPO equipment is signalled on separate highways from each equipment, the sources of fault messages being the call-trace equipment, marker, supervisory processing unit (SPU) and main control unit (MCU). Messages arising from routers, path failure information, progress faults and parked lines, are assembled and sent to the FPO via the MCU. Only one source is able to seize the FPO at any one time and, if there is a simultaneous seizure, the message with highest priority is accepted first. A block diagram of the FPO equipment is given in sketch (b).

(ii) The information provided by the traffic recorder is used to assess the traffic carried by the exchange equipment. As the traffic is recorded regularly, it is possible to assess the loading of equipment at various stages in an exchange so as to indicate the need for additional equipment when necessary.

Artificial traffic equipment can be used to obtain a rapid assessment of the quality of service provided by exchanges and, by testing the entire switching paths of the exchange and indicating when faults are detected, it is possible to detect some obscure faults that may not be detected by on-site routers. Maintenance effort can be directed to points of high



(b)

failure rate and to switching units that are performing unsatisfactorily. Fault recorders enable faulty equipment to be identified and maintenance staff advised. Computer analysis of crosspoint failures can enable commonly recurring failure patterns to be established, and a particular crosspoint fault to be identified.

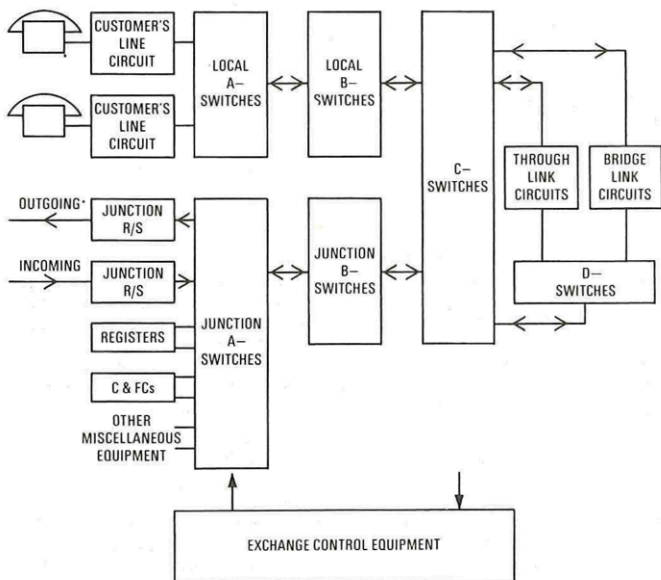
Q3 (a) For the switching network of a large space-division electronic exchange describe:

- with the aid of a block diagram, its essential features;
- how provision is made for different local exchange line and junction calling rates; and
- the switched path restrictions that exist within and between the switching units, and the need for these restrictions. (12 marks)

(b) Explain the term 'serial trunking scheme' (STS) and with the aid of a sketch explain the STS sequence for setting up a local (own-exchange) call. (8 marks)

A3 (a) (i) The essential features of the switch network of a UK TXE4 telephone exchange are given in sketch (a).

The switching network consists of a link trunking scheme of four stages, using reed-relay matrix switches. These stages, known as A-, B-, C- and D-switches, carry both originating and terminating calls.



C & FC: Coin-and-fee check equipment
R/S: Relay-set

(a)

A-Switches These switches are used to connect all circuit terminations to the switching network, local A-switches for customers' lines and junction A-switches for outgoing and incoming junction circuits and miscellaneous equipment connected to the network.

B-Switches These connect A-switches to C-switches.

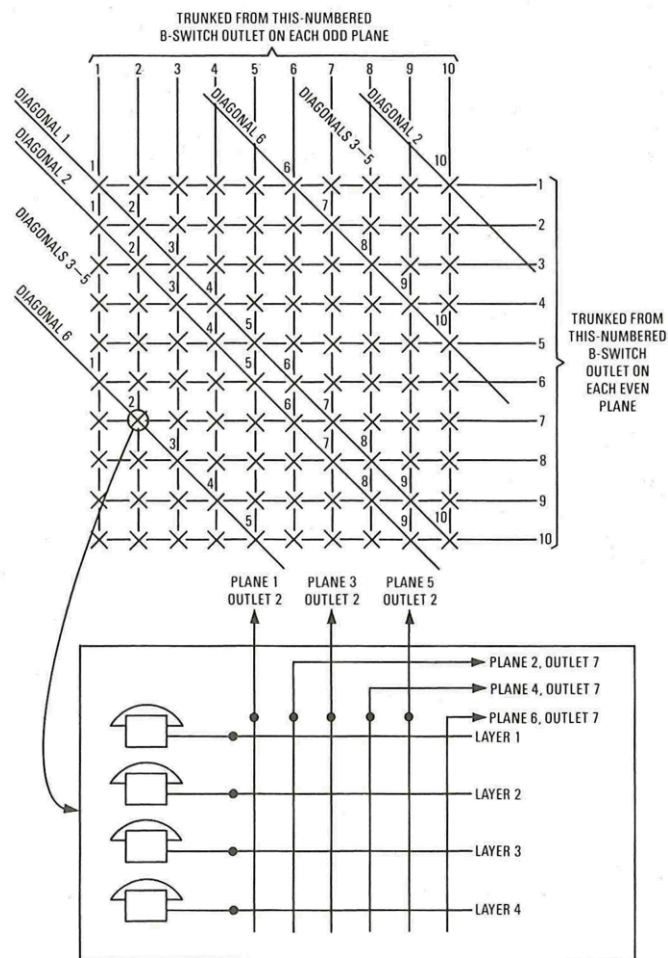
C-Switches These complete connections through the switching network to the link circuits or D-switches.

D-Switches These provide connections between different C-switches throughout the exchange in conjunction with link circuits.

Bridge Links These are used to provide supervisory and signalling functions for incoming junction calls and own-exchange calls.

Through Links These provide a straight-through connection and are used in paths where a transmission bridge or other supervisory function is not required or is provided elsewhere.

(ii) A fully equipped local A-switch can cater for up to 400 subscribers' lines. Ten individual matrices are grouped together to form a row of A-switches which have 40 outlets (10×4) for customers' lines and, assuming 6 planes, 60 inlets (10×6) for B-switch terminations. Sketch (b) shows the way in which the A-switches are arranged in layers.



(b)

Within a layer, each of the 100 lines has a different pattern of connection to the A-B trunks. It can be seen that each of the 10 lines on diagonal 1 is connected to the same numbered B-switch on both odd-numbered and even-numbered planes. On diagonal 2, each of the 10 lines is connected on odd planes to B-switch outlet B and, on even planes, to B-switch outlet B + 1. This pattern recurs so that, in general, the 10 lines on diagonal K are connected on odd-planes to B-switch outlet B and, on even planes, to B-switch outlet B + K - 1. A fully-equipped customers' A-switch is encountered only at average customer calling rates of about 0.02 erlangs. To match high calling rates up to 0.35 erlangs, no customer connections are made to one or more of the diagonals; the number of diagonals left unconnected increases as the calling rate increases.

[Tutorial Note: The method of depicting one layer of the TXE4 customers' A-switch used in sketch (b) enables the pattern of interconnecting, and the derivation of the term *diagonal* to be seen. Each complete customers' A-switch can be visualised as four such layers stacked together.]

Up to 12 of the 18 B-switches in any sub-unit can be allocated to serve junction A-switches. Only diagonal number 1 is provided, but this may have up to six layers; thus up to 60 terminations can be accommodated on each junction A-switch.

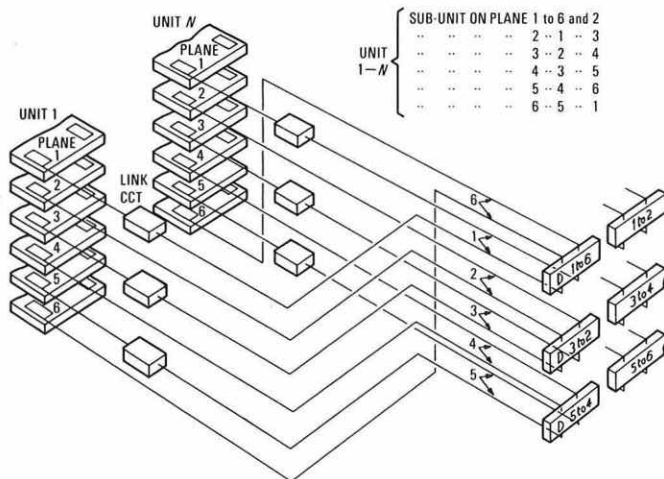
(iii) The switched path restrictions that exist within and between the switching units, and the reasons for these restrictions are as follows:

Sectionalisation

The B and C steps are divided into BC sub-units, each meeting the full range of switching requirements for a proportion of the total traffic handled by the unit. Sectionalisation increases the security of the switching network.

Sub-Unit Interconnection

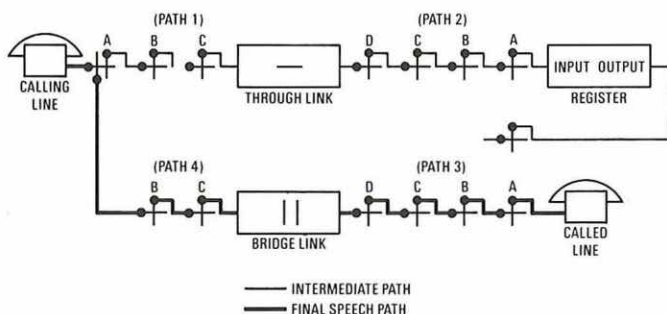
The means by which the units and sub-units are interconnected by using the D-switches and links is shown in sketch (c). The C-switch inlets of sub-units on the odd planes, that is, 1, 3, 5, are connected to D-switches via link circuits, but the C-switch inlets on even planes, that is, 2, 4 and 6, are connected directly to D-switches. These connections allow choices of path between sub-units on adjacent planes but no others. For example, a call routed through plane 3 sub-unit of unit 1 would be connected via a free link circuit to a D-switch. The connection from the other side of this D-switch would be either to plane 2 sub-units or to plane 4 sub-units. Paths cannot be set up within the same sub-unit, between sub-units in the same plane or between sub-units in non-adjacent planes. In this context, the top and bottom planes are regarded as adjacent; for example, planes 1 and 6 in sketch (c) are adjacent planes. This restriction of path accessibility between sub-units considerably reduces requirements for crosspoints and simplifies control procedures, whilst maintaining sufficient switching paths to satisfy traffic considerations.



(c)

(b) Serial trunking is the use, on one call, of two or more switching paths.

The serial trunking sequence for setting up a local (own-exchange) call is shown in sketch (d).



(d)

When a customer lifts the telephone handset, the loop is detected by the line scanner associated with the line, and a main control unit stores details of the line in order to locate it. The main control unit establishes a free path through the switching area to a free register. This is identified as half paths 1 and 2 via the through link in sketch (d). When the path is proved, dial tone is sent to the customer from the register.

The customer dials and, for an own-exchange call, the main control unit locates the called customer. Further analysis is required; for example, if the called line is barred service, the call is connected to number-unobtainable tone. If the call is to proceed, a free path is set up as half-paths 3 and 4 via the bridge link in sketch (d). When the path is proved, the original path 1/2 and the register are released. The called line is then rung and, in due course, conversation can take place.

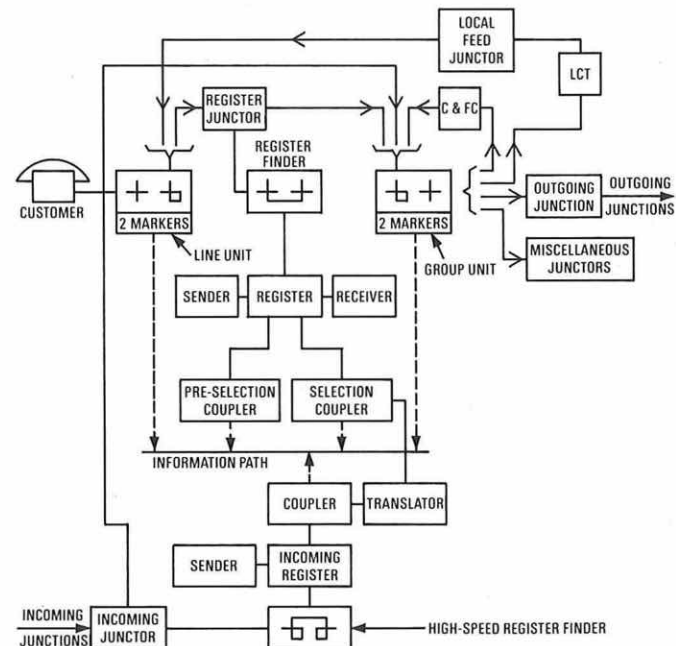
Q4 For a Pentaconta-type crossbar exchange

(a) sketch and label a trunking diagram which includes the essential items in both the switching and control areas; (7 marks)

(b) explain, with the aid of the trunking diagram in (a), how the path is selected and switched from the calling exchange line circuit to a free register; and (7 marks)

(c) describe, with a block diagram, how PBX working is provided. (6 marks)

A4 (a) Sketch (a) shows the trunking of a Pentaconta-type crossbar exchange. In the UK, this type of exchange is known as TXK3.



C & FC: Coin-and-fee check equipment
LCT: Local call timer

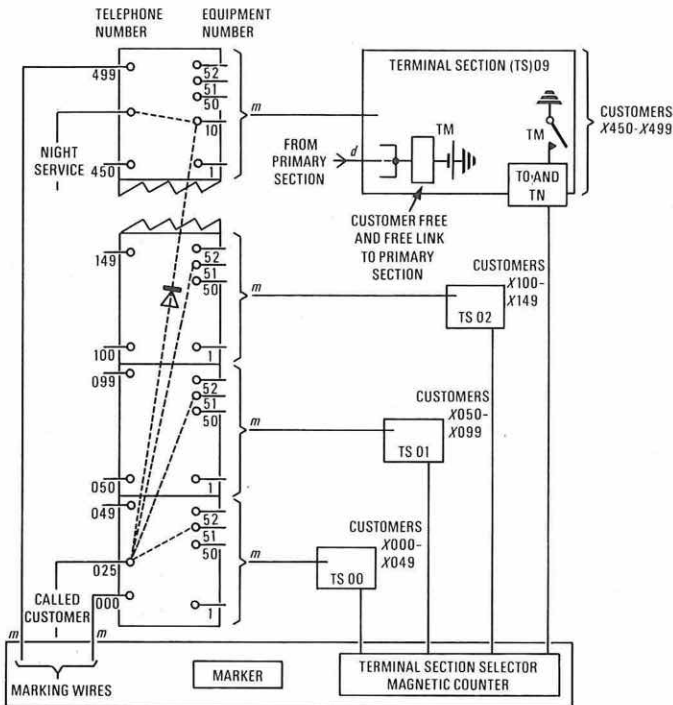
(a)

(b) The calling customer's line unit sends a *start* signal to a register finder, which seizes a free register and connects it, via a register junctor, to a free inlet of the line unit. The line unit marker is now engaged to prepare a path, through the multiswitches, connecting the seized inlet to the calling customer's outlet. When the preparation is complete, the marker uses the information path to inform the register of the type of line that is about to be connected. After storing this information, the register causes the prepared path to be switched, and connects dial tone to the caller.

(c) Sketch (b) shows the arrangements in the TXK3 system for accommodating PBX working for small groups. The publication of one number is sufficient for customers to be given automatic selection of any free line in the group. Sketch (b) shows the marker number frame, which is the point where marking wires (m) from the marker are jumpered to the wires that go to the customers' outlet circuits. For PBX lines, jumpers are taken from the terminal to all the lines in the group, as shown in the sketch. Thus the marking earth is received in all of the terminal sections for the lines, and, if the particular section has its line free and has a free link to the calling primary section, the TM relay is operated. Unlike a normal call, where only one section is involved, there

are now several, and therefore a selection must be made as to which section is used. This is determined by the marker, which has a magnetic counter as a selection device. The TN relay operates in the chosen section and the call is set up through it.

It can be seen that lines are selected at random, and therefore the selection of a particular line cannot be guaranteed; however, an individual line can be called by teeing a subsidiary number to it, as shown in sketch (b).



(b)

Q5 (a) For a loop-disconnect (Strowger) DC pulsing system

- state the normal pulsing speed and ratio,
- state the tolerances allowed for in the circuit design for both the pulsing speed and ratio, and
- calculate for the tolerances in (ii) the minimum pulse 'make-and-break' periods. (6 marks)

(b) Explain how a selector could understep or overstep when the line has

- low insulation resistance, and
 - high loop resistance. (10 marks)
- (c) Describe the possible effect on pulsing performance when a capacitive spark quench is used to protect the pulsing contacts. (4 marks)

A5 (a)

- The normal pulsing speed is 10 pulses/s, of ratio 33 ms MAKE period and 66 ms BREAK period.
- The tolerances allowed for in the circuit design are a pulsing speed of 7-12 pulses/s, with a ratio between 37% make, 63% break and 28% make, 72% break.
- The minimum pulse occurs at 12 pulses/s.

Total pulse = 83 ms
63% BREAK = 53 ms
37% MAKE = 30 ms

The minimum BREAK period is therefore 53 ms.

72% BREAK = 60 ms
28% MAKE = 23 ms

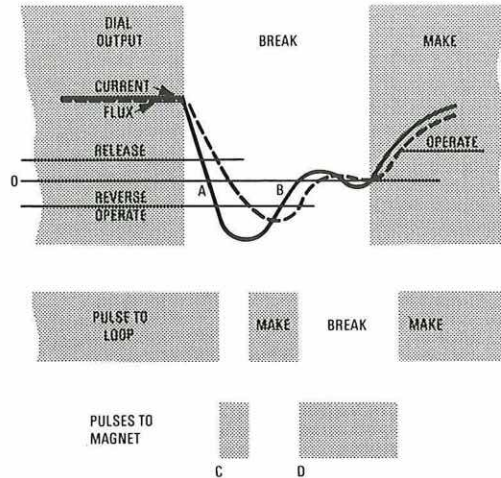
The minimum MAKE period is therefore 23 ms.

(b) (i) When a line has a low insulation resistance (high leakage) the pulsing relay is partially energised during the BREAK periods so that the operate time is reduced. The release time is increased due to the slug effect of the leakage. The effect of the leakage is to increase the period

for which the MAKE contact is closed, and reduce the period for which the BREAK contact is closed; as a consequence, the operation of the selector B relay is aided, but the conditions tend to cause the selector magnet to fail to step (understepping).

(ii) When a line has high loop resistance, the operate time of the pulsing relay is increased and the release time is reduced. The effect of high loop resistance is to cause the B relay to release during pulsing and thus cause the selector magnet to overstep.

(c) The capacitor spark quench is connected across the dial pulsing contacts. When the dial springs MAKE, the capacitor has no effect on the pulsing relay because it is virtually short circuited by the springs. When the dial springs open on BREAK, the magnetic field of the pulsing relay generates an induced voltage which charges the capacitor to a much higher voltage than that of the battery. This charging current is in the form of a damped oscillation, and the delay waveform does not fall so rapidly as it would without the capacitor, as shown in the sketch.



When the flux in the pulsing relay has collapsed, the capacitor discharges its high voltage back through the pulsing relay, tending to set up a current in the reverse direction, as shown between points A and B in the sketch, and to re-operate the relay. The relay, having released for a short time and then re-operated, may give rise to a false pulse if the magnet is sufficiently sensitive; if it is not, the effective BREAK period is reduced by the time period CD.

Q6 For a voice-frequency (VF) inband signalling system

(a) explain the term 'speech immunity' and list THREE speech-frequency characteristics that are used in the design of the VF receiver to obtain it. (5 marks)

(b) describe with a circuit element how the VF receiver responds to both speech and signalling frequencies, and (8 marks)

(c) state a typical range of input signal level over which the VF receiver will operate, and explain how the VF receiver is designed to function correctly over this range of input levels. (7 marks)

A6 (a) For a voice-frequency (VF) inband signalling system, the term speech immunity means that steps are taken in the design to prevent speech operating the signalling relay.

The following five speech/frequency characteristics are used in the VF receiver to achieve speech immunity: [only three were asked for]

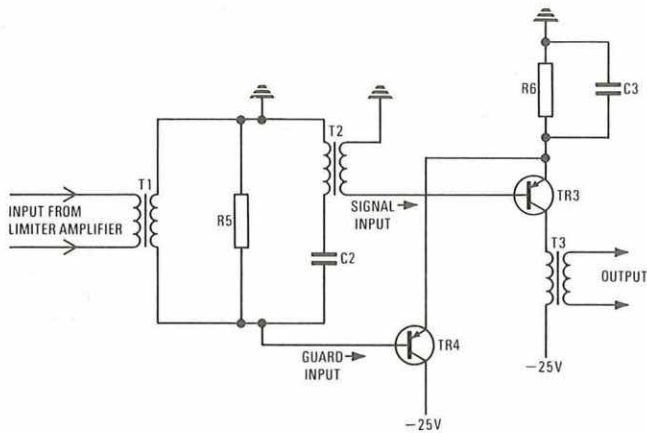
(i) When the signalling frequency appears in speech, it is usually accompanied by other frequencies.

(ii) Some speech frequencies are seldom produced by the voice and, even when they are, their energy level is low.

(iii) When the signalling frequency appears in speech, it is usually only for short periods. The receiver can be made to respond only to signal frequencies having a predetermined minimum duration.

(iv) A signal which is compounded from two frequencies is less liable to occur and persist in speech than a signal made up of a single frequency.

(v) The voice cannot readily imitate two or more short pulses of tone that are amplitude or frequency modulated.



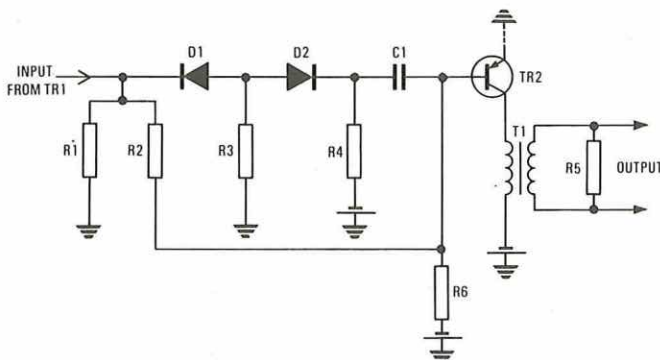
(a)

(b) Sketch (a) indicates the circuit elements in a VF receiver that respond to both speech and signalling frequencies. The circuit elements consist of a frequency-selective circuit, which feeds a signal-and-guard comparator circuit.

The frequency-selective stage contains a series tuned circuit designed to resonate at the signal frequency, 2280 Hz. A maximum voltage is produced in the transformer T2 secondary at resonance. An effective output is produced only within ± 50 Hz of the signal frequency. A guard voltage, which is not frequency dependent, is developed across resistor R5 and applied to the base of transistor TR4.

Transistors TR3 and TR4, plus associated components, make up the signal-and-guard comparator circuit. Transistor TR4 conducts on each negative half cycle of the guard input voltage and in so doing charges capacitor C3 to the peak of the guard voltage. Resistor R6 provides a discharge path for the capacitor so that the voltage level across it follows roughly the input signal; the circuit time constant, however, is such that an effective bias voltage exists across it for a period of 4 ms after the ground input signal has ceased. The delay time incorporated in this guard bias circuit is a factor in obtaining voice immunity should 2280 Hz appear with other frequencies, as in speech. The guard circuit, therefore, tends to bias off transistor TR3 until its base is made more negative than its emitter by an input from the 2280 Hz resonant circuit. Transistor TR3 then conducts, driving a current pulse through the primary of transformer T3 for each negative half cycle applied to its base. The primary and secondary windings of transformer T3 are connected so that, each time the signal in the primary decays, the input signal to transistor TR3 is negative and it conducts.

(c) A typical range of input signal level over which the VF receiver operates is +3 dBm to -15 dBm. The VF receiver has a limiter and current amplifier which enables it to function correctly over this range; the essential elements are given in sketch (b).



(b)

Diodes D1 and D2 form a clipping stage to limit the input swings into transistor TR2. When no signal is present, both diodes conduct but, when a signal is received from transistor TR1, the impedance of the diodes increases or decreases. For positive signals, the impedance of diode D1 increases until it ceases to conduct; if the signal is negative, the impedance of diode D2 increases toward cut-off. The input signal swing is therefore limited and a square-wave output is developed in resistor R5 across the output transformer T1, a step-down transformer used to increase the current which is then passed onto the frequency-selective circuit.

Q7 For a digital switching system, explain

- why fewer crosspoints are required to fully interconnect the same number of incoming and outgoing circuits compared with a space-division switching system; (4 marks)
- the terms 'space switching' and 'time switching'; (4 marks)
- the condition occurring in the digital exchange which makes time switching between circuits necessary; (3 marks)
- with a sketch, the principle of time switching; and (6 marks)
- how the signalling information is conveyed by the channel time-slots through the system. (3 marks)

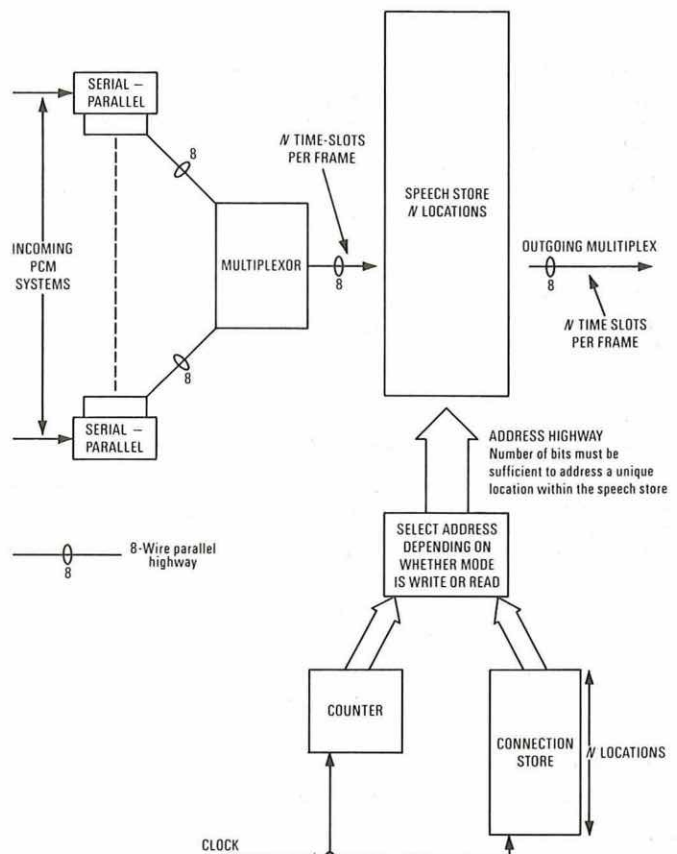
A7 (a) For a digital switching system, fewer crosspoints are used compared with an equivalent-size space-division switching system, because advantage can be made of the integration of digital transmission and digital switching. By directly terminating digital transmission systems on digital switches, incoming and outgoing circuits can be accessed directly by using digital techniques, because they occupy discrete time-slots within the system. Within the digital switch design, some space switches are used, but considerable economy is achieved since these are shared across the channel time-slots so that the crosspoint configurations change at the rate of appearance of the time-slots. For space-division switching systems, circuits have to be realised as discrete 2-wire paths within the system and the crosspoints are held for the duration of the particular calls.

(b) The term *space switching* is used to describe the spatial connection of two different links or highways in the trunking.

The term *time switching* is used to describe the process whereby the contents of an incoming time-slot can be connected to any outgoing time-slot, by delaying the incoming time-slot by the required number of time-slots.

(c) In a digital exchange, there are a number of incoming and outgoing circuits occupying time-slots within digital transmission systems, and it is necessary to be able to connect any incoming time-slot to any outgoing time-slot. It is possible to use a space switch to interconnect time-slots in different digital transmission systems; however the space switch can only connect together time-slots which occur at the same instants of time. In order to connect any incoming time-slot to any outgoing time-slot, it is necessary to delay the channel information in an incoming time-slot, until an appropriate moment when it may be transmitted in the outgoing time-slot.

(d) The principle of time switching is shown by the simplified diagram of a time switch shown in the sketch.



The time switch consists of two basic parts: a speech store which contains one frame of incoming pulse-code modulation (PCM) words and a connection store which controls the addressing of the speech store.

A word is written into the speech store as it comes in, and some time later in the frame, on the appropriate outgoing time-slot, it is read out from the store.

The connection store contains the address of the speech store location to be accessed on each time-slot of the multiplex. As the connection store does not need to be random access, it can be of the recirculating shift register type.

(e) The signalling information is conveyed in different ways, depending on the particular type of digital transmission system. For the UK digital switching system, customers' signalling on the line is detected during the initial setting up of a call by the central processor. After the processor determines the call destination, signalling information is no longer conveyed within the speech channel but is conveyed within a separate time-slot within the system. For the CCITT 30-channel digital transmission system, the signalling information for all of the channels is contained in a separate time-slot, known as *time-slot 16*. Within the digital switching system, time-slot 16 information can be accessed and the signalling information extracted by the processor. The signalling information may contain routing digits or supervisory signals necessary to control the setting up of the call. Common-channel signalling is used between digital exchanges, whereby signalling messages are conveyed within a dedicated signalling channel.

Q8 (a) For the telephone exchange maintenance

(i) explain the terms 'corrective' and preventive maintenance; and
(ii) state which of the methods in (i) should be used with modern common-control switching systems, giving a reason for the choice. (8 marks)

(b) For the access arrangements of an automatic routine tester (routiner),

(i) describe with a block diagram two access arrangements by which it is connected to the exchange switching equipment, including the number of access points in each arrangement; and

(iii) state for EACH arrangement a typical item of switching equipment that would be connected to the routiner and explain why alternative access arrangements are considered necessary. (12 marks)

Q9 (a) For a large space-division electronic exchange,

(i) list the rates at which scanning of the exchange lines, registers and incoming junctions occur;

(ii) explain with a block diagram how an exchange-line calling condition is detected; and

(iii) describe, in general terms, how each exchange-line is provided with a unique position in the scanning sequence. (10 marks)

(b) For the 5005 type crossbar exchange

(i) explain with a trunking diagram how the second-attempt facility is provided; and

(ii) list the basic sequence of events that follow the failure of a second attempt to establish a speech path. (10 marks)

Q10 For a delay-call single-server system

(a) explain queue discipline in terms of 'first-come first-served'; (3 marks)

(b) state TWO disadvantages to a caller of random queue dispersal; and (4 marks)

(c) if the average holding time of a single server is 150 ms and the mean delay of all the calls is 250 ms, calculate

(i) the number of offered calls during the busy hour,
(ii) the probability of a call being delayed, and
(iii) the number of busy-hour calls that will not be delayed. (13 marks)

A10 (a) For a delay-call single-server system, the queue discipline known as *first-come first-served*, is where a queue is formed in front of the server in order of arrival, and the queue is dispersed in order of arrival so that the call at the head of the queue is allocated to the server when it next becomes available.

(b) Two disadvantages to a caller of random queue dispersal are:

(i) being served quickly is dependent on luck since calls are served in a random manner and other calls arriving could well be served first, and
(ii) there is a tendency for callers waiting a long time to give up and try calling again, which tends to create false traffic.

(c) (i) For a single server, it is assumed that the holding time has a negative-exponential distribution and that calls arrive at random.

Let C = number of calls per hour,
 H = average holding time in hours,
 M = average waiting time of calls, and
 A = traffic offered in erlangs.

Average waiting time of calls,

$$M = \frac{AH}{1-A}.$$

$$\therefore 0.25 = \frac{A \times 0.15}{1-A}.$$

$$\therefore 0.25(1-A) = 0.15A.$$

$$\therefore 0.4A = 0.25.$$

$$\therefore A = \frac{0.25}{0.4},$$

$$= 0.625 \text{ erlang.}$$

$$A = CH.$$

$$\therefore C = \frac{A}{H},$$

$$= \frac{0.625}{0.15/3600},$$

$$= 15000.$$

But,

Thus there are 15000 calls in the busy hour.

(ii) The probability of a call having to queue on arrival is

$$P(\geq 0) = CH = A,$$

$$= 0.625.$$

(iii) The number of busy hour calls that are not delayed

$$= \text{total number of calls offered}$$

$$\times \text{probability of calls not being delayed,}$$

$$= 15000 \times (1 - 0.625),$$

$$= 15000 \times 0.375,$$

$$= 5625.$$

Answers contributed by J. R. Bush

BUSINESS AND TECHNICIAN EDUCATION COUNCIL

National Certificate in Telecommunications

Sets of model questions and answers for Business and Technician Education Council (BTEC) units are given below. The questions illustrate the types of questions that students may encounter, and are useful as practice material for the skills learned during the course.

Where additional text is given for educational purposes, it is shown within square brackets to distinguish it from information expected of students under examination conditions. Representative time limits for questions are shown, and care has been taken to give model answers that reflect these limits.

We would like to emphasise that the questions are not representative of questions set by any particular college.

BTEC: TRANSMISSION SYSTEMS II

The following questions are based on the BTEC's unit U81/746. Students are advised to read the notes above

Q1 State the relationship between frequency, velocity and wavelength and quote the units used. (1 min)

A1 Velocity (metres/second) = frequency (hertz) $\times$ wavelength (metres).

Q2 (a) What is the velocity of light in free space?

(b) A 15 MHz signal is transmitted in a cable with a velocity 0.8 times the velocity of light. Determine the wavelength of the signal. (2 min)

A2 (a) 3×10^8 m/s.

$$\begin{aligned} \text{(b)} \quad \text{Wavelength} &= \frac{\text{velocity}}{\text{frequency}}, \\ &= \frac{0.8 \times 3 \times 10^8}{15 \times 10^6} \\ &= \underline{16 \text{ m.}} \end{aligned}$$

Q3 What frequency ranges are used for the transmission of the following:

- (a) commercial speech,
- (b) high-quality music,
- (c) multichannel voice-frequency (MCVF) telegraph channels, and
- (d) 625-line television pictures. (2 min)

A3 (a) 300–3400 Hz
(b) 30 Hz–15 kHz
(c) 120 Hz
(d) 5.5 MHz

[Tutorial Note: High-quality music, in this case, refers to a very-high-frequency modulated broadcast. Acceptable commercial music frequency over land lines is 50 Hz–6.4 kHz.]

Q4 The block diagram of a telecommunications system in Fig. 1 shows the power ratios of each item. Find the power at B if 1 mW of power is applied to point A. Also state whether there is a loss or gain at the output. (2½ min)

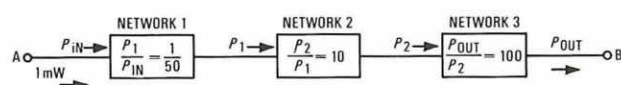


Fig. 1

A4 The overall power ratio

$$= \frac{P_{\text{out}}}{P_{\text{in}}} = \frac{1}{50} \times 10 \times 100 = 20.$$

Thus, if 1 mW is applied at A, the output at B is

$$P_{\text{out}} = 1 \times 20 = 20 \text{ mW.}$$

Thus there is an overall power gain.

Q5 The input power to an amplifier is 30 μ W. If the gain is 40 dB, what is the output? (2½ min)

A5 By definition,

$$40 = 10 \log_{10} \frac{P_{\text{out}}}{P_{\text{in}}},$$

where P_{out} is the power at the output, and P_{in} is the power at the input.

$$\therefore \frac{40}{10} = \log_{10} \frac{P_{\text{out}}}{P_{\text{in}}},$$

$$\therefore 4 = \log_{10} \frac{P_{\text{out}}}{P_{\text{in}}},$$

$$\therefore \frac{P_{\text{out}}}{P_{\text{in}}} = \text{antilog } 4.0.$$

$$\therefore \frac{P_{\text{out}}}{P_{\text{in}}} = 10^4.$$

$$\begin{aligned} \therefore P_{\text{out}} &= P_{\text{in}} \times 10^4, \\ &= 30 \times 10^{-6} \times 10^4, \\ &= \underline{0.3 \text{ W.}} \end{aligned}$$

Q6 The telecommunications system in Fig. 2 shows various gains and losses. The output power is required to be –3 dBm. What value of input power is needed to achieve this? (3 min)



Fig. 2

A6 Total gain = 27 + 30 + 8,
= 65 dB.

Total attenuation = 10 + 21 + 15 + 14,
= 60 dB.

Overall power gain = 65 – 60,
= 5 dB.

Required output power = –3 dBm.

Output power = overall power ratio + input power.

–3 dBm = 5 dBm + input power.

Input power = –3 – 5,
= –8 dBm.

Q7 Define a decibel and quote a power ratio of 300 in decibels. (2 min)

A7 A power ratio P_1/P_2 can be expressed in decibels (tenths of bels) as

$$10 \log_{10} \frac{P_1}{P_2}.$$

Therefore, a power ratio of 300 in decibels is

$$10 \log_{10} 300 = 10 \times 2.4771, \\ = 24.8 \text{ dB.}$$

Q8 What is 35 mW expressed in dBm? (2 min)

A8

$$35 \text{ mW} \equiv 10 \log_{10} \frac{35 \times 10^{-3}}{1 \times 10^{-3}}, \\ \equiv 10 \times 1.5441, \\ \equiv 15.4 \text{ dBm.}$$

[Tutorial Note: The reference level used is 1 mW and a larger power P watts has a level of x dBm, where

$$x = 10 \log_{10} \frac{P}{1 \times 10^{-3}}]$$

Q9 The current into an amplifier is 60 μ A and the output current is 54 mA. Assuming that the input and output are matched, what is the gain? (2 min)

A9

$$20 \log_{10} \frac{54 \times 10^{-3}}{60 \times 10^{-6}} = 20 \log_{10} 0.9 \times 10^3, \\ = 20 \log_{10} 900, \\ = 20 \times 2.9542, \\ = 59 \text{ dB.}$$

Q10 From the circuit diagram shown in Fig. 3 and the data given in Table 1, explain if the maximum power transfer theorem is confirmed. (3 min)

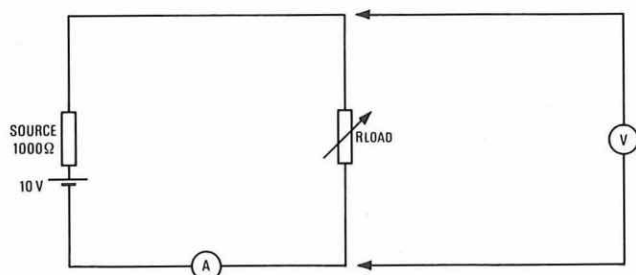


Fig. 3

Table 1

$R_{\text{LOAD}}(\Omega)$	400	800	900	950	1000	1050	1100	1200	1400
Power ($V \times I \text{ mW}$)	20.3	24.6	24.8	24.9	25.0	24.9	24.8	24.7	24.2

A10 From the data, maximum power is transferred when the load resistor is 1000 Ω , which is equal to the source resistance of 1000 Ω (see Fig. 3). Therefore, the maximum power transfer theorem is confirmed, because it states that maximum power is transferred from a source to a load when the resistance of the load is equal to the resistance of the source.

Q11 The noise at the output of an amplifier is 2 mW and the output signal power is 4 W. Calculate the signal-to-noise ratio. (1.5 min)

A11 Signal-to-noise ratio

$$= \frac{\text{signal power at the output}}{\text{noise power at the output}},$$

$$= \frac{4}{2 \times 10^{-3}}, \\ = 2000.$$

Q12 With reference to Fig. 4,

- (a) what is the power relationship between a signal applied at A and the output at B and C, and
(b) what is the power relationship between a signal applied at C and its output at A and B? (2 min)

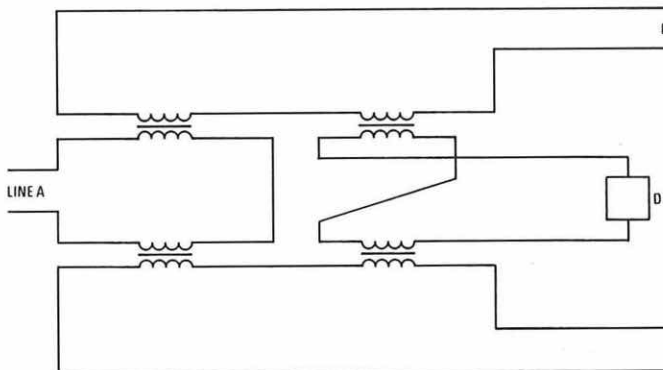


Fig. 4

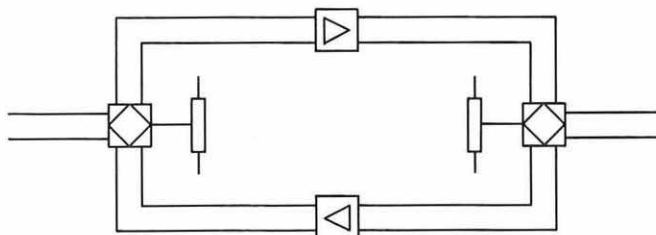
- A12 (a) The signal power at either B or C is half of that at A.
(b) (i) The signal power at A is half of that at C.
(ii) The signal power at B is a very small fraction of that at C.

[Tutorial Note: This assumes that the impedance across D is identical to that across A.]

Q13 Draw a simplified block diagram, using standard symbols for terminating units and line amplifiers, of a 4-wire amplified circuit and state

- (a) the loss in decibels from 2-wire to 4-wire,
(b) the loss in decibels from receive 4-wire to 2-wire, and
(c) the loss in decibels from receive 4-wire to transmit 4-wire. (3 min)

A13



- (a) 4 dB,
(b) 3.5-4 dB, and
(c) greater than 35 dB.

Q14 Which of the following frequencies is the most suitable as a carrier when the baseband frequency range is 50 Hz-6 kHz:

- (a) 50 Hz,
(b) 3 kHz,
(c) 6 kHz, or
(d) 60 kHz.

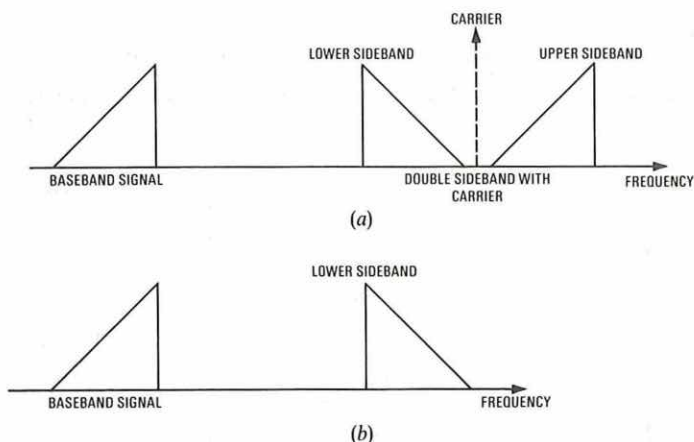
(1 min)

A14 (d) 60 kHz.

[Tutorial Note: The carrier frequency should be higher than the highest baseband frequency to be transmitted.]

Q15 Explain simply with the aid of frequency spectrum diagrams how a single-sideband suppressed-carrier signal contains the same information as a double-sideband amplitude modulated signal, and explain briefly how this is achieved. (6 min)

A15 In a double-sideband amplitude-modulated signal (see sketch (a)), the carrier contains none of the intelligence represented by the modulation, and each sideband considered separately contains all the information present in the modulated wave; so a single sideband with the carrier suppressed (see sketch (b)) conveys all the information in the baseband.



To eliminate the carrier, a modulator which suppresses the carrier from the output would be used. To suppress the upper sideband, a filter is placed in the output. This filter, which needs to be very accurate, stops all frequencies above the carrier (in this case), thus leaving only the lower sideband.

Q16 What types of filters have the voltage/frequency graphs shown in Fig. 5? (2 min)

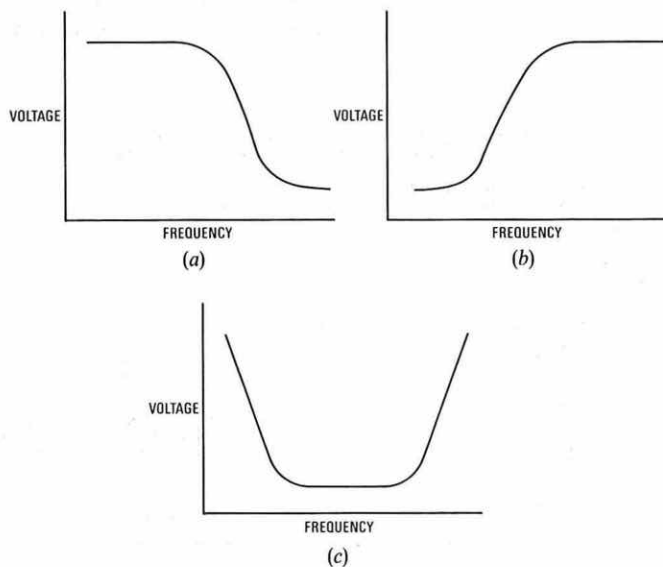


Fig. 5

- A16** (a) Low-pass filter.
(b) High-pass filter.
(c) Band-stop filter.

Q17 Explain the function of a filter. (1½ min)

A17 The function of a filter is to attenuate certain ranges of frequency, yet offer little attenuation to other frequencies.

Q18 What is the main advantage of a quartz crystal filter over a bandpass LC filter? (2 min)

A18 A much sharper frequency cut-off (that is, maximum selectivity) can be obtained from a quartz crystal filter. This would be required for use in the radio-frequency spectrum.

Q19 Fig. 6 shows a number of filters in tandem. State the range of frequencies which could be present at the output of filter 3. (3 min)

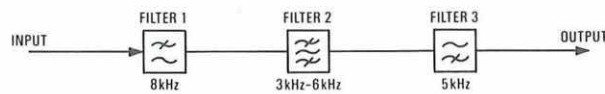
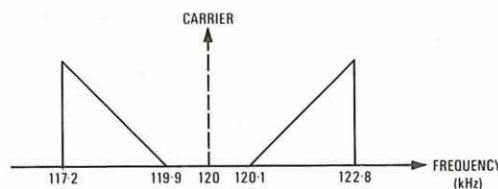


Fig. 6

A19 At the output of filter 3, the frequency range is 5–6 kHz.

Q20 A radio-frequency carrier wave is amplitude modulated by a band of frequencies 100–2800 Hz. If the carrier frequency is 120 kHz, draw the frequency spectrum diagram to show what frequencies are present and calculate the bandwidth.

A20



$$\text{Bandwidth} = 122.8 - 117.2 = 5.6 \text{ kHz.}$$

Q21 Give the main advantages of a single-sideband suppressed-carrier (SSBSC) signal over a double-sideband (DSB) signal. (2½ min)

A21 There are two main advantages:

(a) **Bandwidth** The bandwidth of a DSB signal is up to twice that of a SSBSC signal.

[Tutorial Note: Each sideband contains the full information of the modulating baseband signal. Elimination of either upper or lower sideband reduces the bandwidth by up to a half.]

(b) **Power** The carrier contributes a considerable amount to the overall power of a DSB signal. Suppression of the carrier in both DSB and SSBSC signals results in a large saving of power and smaller amplifiers.

Q22 A carrier wave with amplitude 60 mV is amplitude modulated by a signal to a depth of 80%. What is the maximum peak amplitude and the minimum peak amplitude of the modulated carrier? What is the peak modulating signal voltage? (4 min)

A22 If B is the peak modulating signal voltage and A is the amplitude of the modulated carrier, then

$$\frac{B}{A} = 80\%.$$

$$\frac{B}{60} \times 100 = 80.$$

$$B = \frac{80 \times 60}{100},$$

$$= 48 \text{ mV.}$$

Therefore, the maximum peak modulating signal voltage is

$$60 + 48 = 108 \text{ mV.}$$

Therefore, the minimum peak modulating signal voltage is

$$60 - 48 = 12 \text{ mV.}$$

Q23 Complete the following statements with reference to frequency modulation.

- (a) The amount by which the carrier frequency deviates from the nominal value is proportional to the ... (i) ... of the ... (ii) ... signal.
(b) The frequency swing is equal to ... the frequency deviation.
(c) The modulation index is equal to the ratio of the ... (i) ... to the ... (ii) ...

- A23** (a) (i) amplitude
(ii) modulating
(b) twice
(c) (i) frequency deviation
(ii) modulating frequency.

Q24 A frequency-modulated signal has a modulation index of 7. If the frequency swing is 120 kHz, what is the modulating frequency and what is the bandwidth required? (2½ min)

- A28** (a) 4 kHz
(b) 48 kHz
(c) 240 kHz

A24 Modulation index = $\frac{\text{frequency deviation}}{\text{modulating frequency}}$

$\therefore 7 = \frac{60}{\text{modulating frequency}}$

Modulating frequency = $\frac{60}{7} = 8.6 \text{ kHz}$

Bandwidth = $2 \times (60 + 8.6)$

= $2 \times 68.6 = 137.2 \text{ kHz}$

Q25 Explain what prevents the acceptable transmission of the waveform shown in Fig. 7 over the analogue telephone network. (3 min)

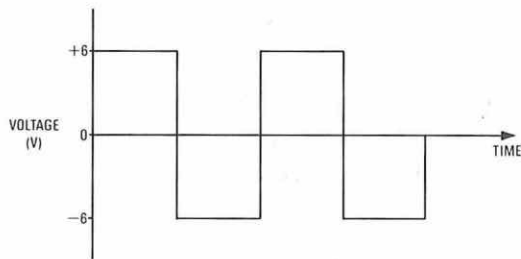


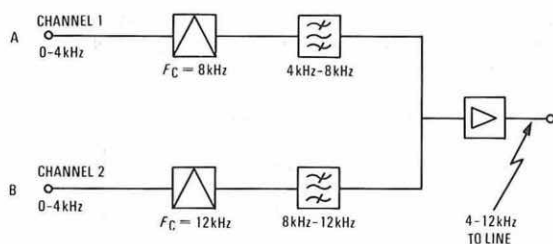
Fig. 7

A25 Fig. 7 shows a binary data signal, which consists of a DC component equal to the average value of the waveform plus a fundamental frequency and a number of harmonics. This signal would be seriously distorted by

- (a) long cable circuits,
(b) transmission bridges in telephone exchanges,
(c) multichannel telephony systems, and
(d) the line amplifiers of audio-frequency junctions and/or trunks.

Q26 Draw a simple block diagram of a two-channel frequency-division multiplex system, with 4 kHz channels and carrier frequencies of 8 kHz and 12 kHz. Indicate the frequencies of the signals sent to line. (4 min)

A26



Q27 In a multichannel frequency-division multiplex system,

- (a) how many channels are there in a group,
(b) how many groups are there in a supergroup,
(c) how many supergroups are there in a hypergroup,
(d) how many channels are there in a supergroup, and
(e) how many channels are there in a hypergroup?

(2 min)

- A27** 1(a) 12
(b) 5
(c) 15 or 16
(d) 60
(e) 900 or 960

Q28 With reference to frequency-division multiplex systems, quote the bandwidth of the following:

- (a) a channel,
(b) a group, and
(c) a supergroup.

(2 min)

Q29 Explain briefly the following terms as used in time-division multiplex systems:

- (a) sampling,
(b) pulse-amplitude modulated highway,
(c) quantisation, and
(d) coding.

(4 min)

A29 (a) The process of looking at the amplitude of an analogue signal at regular short time intervals via an electronic gate.

(b) A sequential stream of amplitude-modulated samples.

(c) The process of comparing the amplitude of each sample to the closest discrete arithmetic-value level; that is, quantum level.

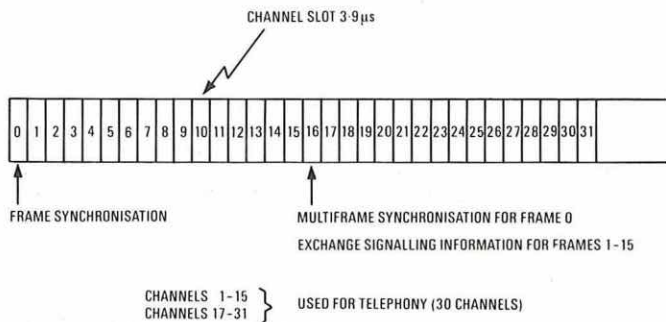
(d) The process of converting the arithmetic numbers representing the quantum levels into binary codes.

Q30 Sketch one frame of a 30-channel time-division multiplex system. Show the number of time-slots and the duration of one time-slot, and indicate which channels are used for

- (a) telephony,
(b) frame and multiframe synchronisation, and
(c) exchange signalling information.

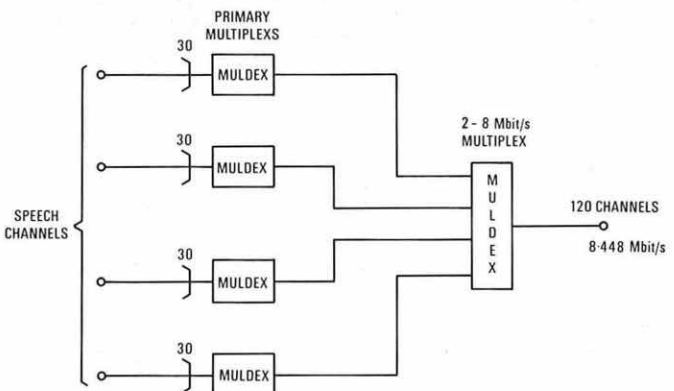
(4 min)

A30



Q31 Draw a block diagram to show how 30-channel pulse-code modulated systems can be assembled into a second-order system. Quote the bit rate to line.

A31



BTEC: ELECTRICAL AND ELECTRONIC PRINCIPLES III

The questions in this paper are based on the following sections of the BTEC's standard unit U81/742: circuit theorems, alternating current circuits, DC transients, transformers and machines. Students are advised to read the notes on p. 52

The time for the questions in Section A is one hour, and $\frac{1}{2}$ hour for each question in Section B.

SECTION A

Q1 Use Norton's theorem to determine the potential difference across the $8\ \Omega$ resistor in the circuit shown in Fig. 1. Both generators have negligible internal impedance.

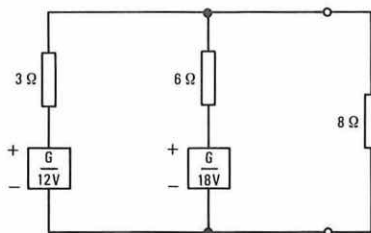
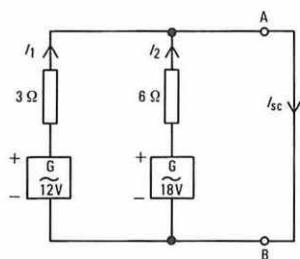
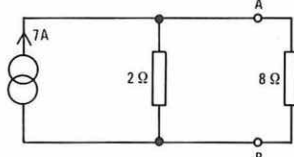


Fig. 1

A1 Sketch (a) shows the $8\ \Omega$ resistor replaced by a short circuit.



(a)



(b)

The current supplied by the 12 V generator, $I_1 = \frac{12}{3} = 4\text{ A}$.

The current supplied by the 18 V generator, $I_2 = \frac{18}{6} = 3\text{ A}$.

Therefore, the short-circuit current, $I_{sc} = I_1 + I_2 = 4 + 3 = 7\text{ A}$.

In sketch (a), with the short circuit removed and each generator replaced by a short circuit (negligible internal impedance), the impedance between points A and B is given by

$$\frac{3 \times 6}{3 + 6} = \frac{18}{9} = 2\ \Omega.$$

The initial circuit is now simplified to the circuit shown in sketch (b).

In sketch (b), the total load on the constant-current generator is given by

$$\frac{2 \times 8}{2 + 8} = \frac{16}{10} = 1.6\ \Omega.$$

Therefore, the potential difference across the $8\ \Omega$ resistor

$$= 7 \times 1.6 = 11.2\text{ V}.$$

Q2 A coil is connected across a 240 V 50 Hz supply, together with a wattmeter and ammeter, as shown in Fig. 2. The wattmeter reading is 15 W, and the ammeter reading is 0.14 A.

Calculate the inductance and the resistance of the coil, assuming that the two meters have a negligible effect on the circuit.

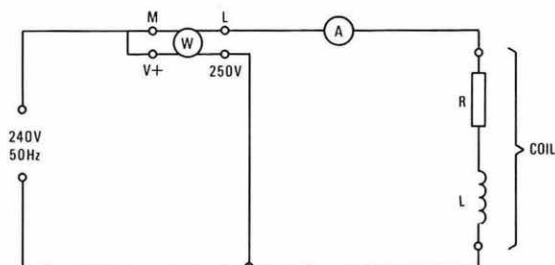


Fig. 2

A2 Power is dissipated only in the resistance of the coil.

If I is the current in the coil, then the power dissipated, P , is given by

$$P = I^2 R.$$

$$\begin{aligned} \therefore R &= \frac{P}{I^2}, \\ &= \frac{15}{(0.14)^2}, \\ &= 765.3\ \Omega. \end{aligned}$$

The impedance of the coil, Z , is given by

$$\begin{aligned} Z &= \frac{V}{I}, \\ &= \frac{240}{0.14}, \\ &= 1714.3\ \Omega. \end{aligned}$$

But, the impedance Z is also given by.

$$Z = \sqrt{R^2 + X_L^2},$$

where X_L is the inductive reactance of the coil.

$$\begin{aligned} \therefore Z^2 &= R^2 + X_L^2, \\ \therefore X_L^2 &= Z^2 - R^2, \\ \therefore X_L &= \sqrt{Z^2 - R^2}, \\ &= \sqrt{(1714.3^2 - 765.3^2)}, \\ &= 1534\ \Omega. \end{aligned}$$

If f is the frequency, then

$$X_L = 2\pi fL.$$

$$\begin{aligned} \therefore L &= \frac{X_L}{2\pi f}, \\ &= \frac{1534}{2\pi \times 50}, \\ &= 4.88\text{ H}. \end{aligned}$$

Q3 A $100\ \Omega$ resistor is connected in parallel with a $2\ \mu\text{F}$ capacitor across a 50 V 400 Hz supply, as shown in Fig. 3. Calculate the total current, I , flowing in the circuit.

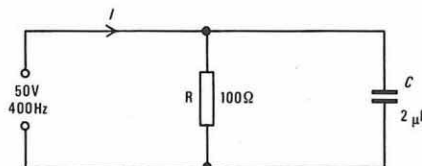


Fig. 3

A3 The current flowing in the resistive branch, I_R , is given by

$$I_R = \frac{V}{R} = \frac{50}{100} = 0.5\text{ A}.$$

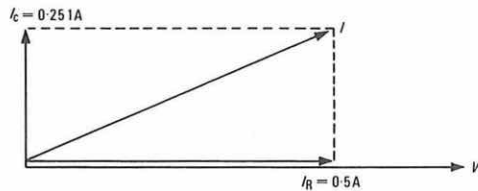
The capacitive reactance, X_C , is given by

$$X_C = \frac{1}{2\pi fC} = \frac{1}{2\pi \times 400 \times 2 \times 10^{-6}} = 198.9\ \Omega.$$

The current flowing in the capacitive branch, I_C , is given by

$$I_C = \frac{V}{X_C} = \frac{50}{198.9} = 0.251\text{ A}.$$

The phasor diagram for this circuit is shown in the sketch.



From the phasor diagram,

$$\begin{aligned} I^2 &= I_R^2 + I_C^2 \\ \therefore I &= \sqrt{(I_R^2 + I_C^2)} \\ &= \sqrt{(0.5^2 + 0.251^2)} \\ &= 0.559 \text{ A.} \end{aligned}$$

Q4 Fig. 4 shows a load connected directly to a signal generator.

In Fig. 5, the load is supplied via a symmetrical π attenuator network. If the loading on the signal source is to be the same for both conditions, determine the required value of R_L .

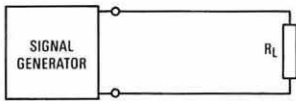


Fig. 4

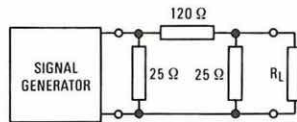


Fig. 5

A4 As the loading on the signal generator is to remain constant, the combined impedance of the π attenuator and resistor R_L must equal the impedance of resistor R_L .

$$\therefore R_L = \frac{\left\{ 120 + \frac{25 \times R_L}{(25 + R_L)} \right\} \times 25}{\left\{ 120 + \frac{25 \times R_L}{(25 + R_L)} \right\} + 25}$$

[Tutorial note: The right-hand side of this equation is the expression for the combined resistances of the network in Fig. 5. It is obtained as follows:

The total resistance of the 25Ω resistor on the right-hand side of the network and resistor R_L is

$$\frac{25 \times R_L}{25 + R_L}$$

This resistance combined with the 120Ω resistor gives

$$120 + \frac{25 \times R_L}{(25 + R_L)}$$

This resistance in parallel with the other 25Ω resistor gives

$$\frac{25 \times \left\{ 120 + \frac{25 \times R_L}{(25 + R_L)} \right\}}{25 + \left\{ 120 + \frac{25 \times R_L}{(25 + R_L)} \right\}}$$

This is the final expression for the resistance of the network.]

$$\begin{aligned} \therefore R_L \times \left\{ 120 + \frac{25 \times R_L}{(25 + R_L)} \right\} + 25R_L \\ = \left\{ 120 + \frac{25 \times R_L}{(25 + R_L)} \right\} \times 25. \end{aligned}$$

$$\begin{aligned} \therefore 120R_L + \frac{25R_L^2}{(25 + R_L)} + 25R_L \\ = 3000 + \frac{625R_L}{(25 + R_L)}. \end{aligned}$$

$$\begin{aligned} \therefore 120R_L(25 + R_L) + 25R_L^2 + 25R_L(25 + R_L) \\ = 3000(25 + R_L) + 625R_L. \end{aligned}$$

$$\begin{aligned} \therefore 3000R_L + 120R_L^2 + 25R_L^2 + 625R_L + 25R_L^2 \\ = 75000 + 3000R_L + 625R_L. \\ \therefore 170R_L^2 = 75000. \\ \therefore R_L^2 = \frac{75000}{170} \\ \therefore R_L = 21 \Omega. \end{aligned}$$

Q5 At the instant switch S in Fig. 6 is closed, the supply current is $500 \mu\text{A}$. The current then decreases exponentially to a value of $400 \mu\text{A}$. Determine the time constant of the discharge circuit. (Assume that the capacitor is initially discharged before S is closed.)

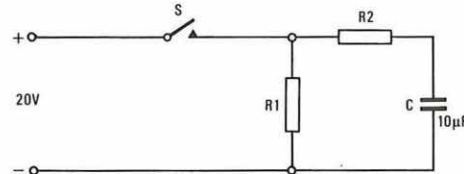


Fig. 6

A5 The initial charge held by the capacitor is 0 C. Therefore, the initial voltage across the capacitor is 0 V, and the potential difference across resistor R_2 is 20 V.

The initial current, I_1 , is therefore determined by the parallel resistance of resistors R_1 and R_2 (R_p).

$$\therefore R_p = \frac{V}{I_1} = \frac{20}{500 \times 10^{-6}} = 40 \text{ k}\Omega.$$

The final current, I_2 , is determined by resistor R_1 .

$$\therefore R_1 = \frac{V}{I_2} = \frac{20}{400 \times 10^{-6}} = 50 \text{ k}\Omega.$$

But,

$$\begin{aligned} \frac{1}{R_p} &= \frac{1}{R_1} + \frac{1}{R_2} \\ \therefore \frac{1}{R_2} &= \frac{1}{R_p} - \frac{1}{R_1} \\ \therefore R_2 &= \frac{1}{\frac{1}{R_p} - \frac{1}{R_1}} \\ &= \frac{1}{\frac{1}{40 \times 10^3} - \frac{1}{50 \times 10^3}} \\ &= 200 \text{ k}\Omega. \end{aligned}$$

The time constant

$$= C(R_1 + R_2) = 10 \times 10^{-6} \times (50 \times 10^3 + 200 \times 10^3) = 2.5 \text{ s.}$$

Q6 The capacitor shown in Fig. 7 is initially fully charged.

Calculate the potential difference across resistor R , 450 ms after switch S is opened.

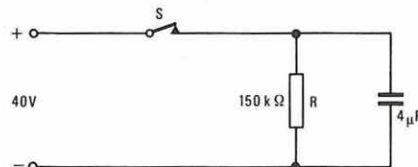


Fig. 7

A6 Initially, the potential difference across the plates of the capacitor is 40 V.

At any instant, the potential difference across resistor R

= the potential difference across the plates of the capacitor,

$$= V e^{-t/(CR)},$$

where V is the initial voltage and t is the time after the switch is closed.
The time constant

$$= CR = 4 \times 10^{-6} \times 150 \times 10^3 = 0.6 \text{ s.}$$

When $t = 450 \text{ ms}$, the potential difference across resistor R

$$= 40 e^{-(450 \times 10^{-3}/0.6)} = 40 e^{-0.75} = \underline{18.89 \text{ V.}}$$

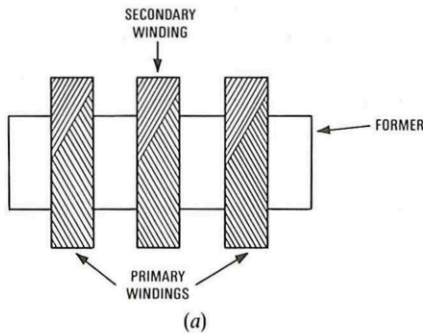
Q7 Explain briefly, with the aid of a sketch, how the self capacitance of the windings in radio-frequency transformers can be minimised.

A7 The two main constructional techniques used are as follows:

(a) The coils are split up into a number of sections or 'pies', producing a much greater separation between the turns.

(b) The coils are wave wound, the wires of one layer crossing those of the layer beneath at an angle. This increases the air space between the layers and consequently reduces the self capacitance. An additional advantage is that the wave wound coils are self supporting.

Sketch (a) shows an example of these two methods of reducing self capacitance. The primary winding is split into two sections and both primary and secondary windings are wave wound.



Q8 The output impedance of an amplifier is 2535Ω . It is required to transfer maximum signal power from the amplifier to a 15Ω loudspeaker load. If a matching transformer is to be used between the amplifier and the load, as shown in Fig. 8, determine a suitable transformer turns ratio.

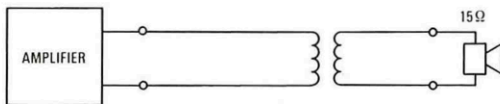


Fig. 8

A8 Maximum power is transferred when the impedance of the load to the amplifier is equal to the output impedance of the amplifier.

This is achieved when the impedance presented across the transformer primary, Z_p , is equal to 2535Ω .

Now,

$$\frac{Z_p}{Z_L} = \left(\frac{N_p}{N_s} \right)^2,$$

where Z_L is the load impedance,
 N_p is the number of turns on the primary winding, and
 N_s is the number of turns on the secondary winding.

$$\begin{aligned} \therefore \frac{2535}{15} &= \left(\frac{N_p}{N_s} \right)^2 \\ \therefore \frac{N_p}{N_s} &= \sqrt{\left(\frac{2535}{15} \right)} \\ &= \sqrt{169} \\ &= 13. \end{aligned}$$

Therefore the required turns ratio is **13 : 1** (step down).

Q9 A 240 V 50 Hz mains transformer has a primary winding with 400

turns and a secondary winding with 50 turns.

Under full load conditions, a power of 200 W is dissipated in a 4Ω load connected across the secondary winding. Determine the per-unit regulation of this transformer.

A9 The 'no load' secondary voltage, V_{NL} , is given by

$$V_{NL} = \frac{N_s}{N_p} V_p,$$

where N_s is the number of turns on the secondary winding,
 N_p is the number of turns on the primary winding, and
 V_p is the voltage across the primary winding.

$$\therefore V_{NL} = \frac{50}{400} \times 240 = 30 \text{ V.}$$

The full-load secondary voltage, V_{FL} , can be determined from

$$P_L = \frac{V_{FL}^2}{R_L},$$

where P_L is the power dissipated in the secondary load, and
 R_L is the resistance of the secondary load.

$$\begin{aligned} \therefore V_{FL}^2 &= P_L R_L \\ \therefore V_{FL} &= \sqrt{(P_L R_L)} \\ &= \sqrt{(200 \times 4)}, \\ &= 28.28 \text{ V.} \end{aligned}$$

$$\begin{aligned} \text{The per-unit regulation} &= \frac{V_{NL} - V_{FL}}{V_{NL}}, \\ &= \frac{30 - 28.28}{30}, \\ &= \underline{0.057.} \end{aligned}$$

Q10 Explain briefly why the slip of an induction motor increases as the load increases.

A10 When the load on a motor increases, the motor is required to produce a larger output torque. The increase in output torque is produced by an increase in the rotor currents. This requires larger EMFs to be induced in the rotor conductors.

The rotor EMFs depend upon the relative velocity between the rotor conductors and the rotating field. A larger rotor EMF requires an increase in this relative velocity, which can only result from a reduction in rotor speed and thus an increase in the slip.

[Tutorial Note: Slip = synchronous speed - rotor speed.

Synchronous speed is the speed of rotation of the rotating magnetic field.]

SECTION B

Q11 (a) A series circuit consisting of a coil, having an inductance of 1.25 mH and a resistance of 60Ω , and an 8 nF capacitor is connected across the output of a signal source. The equivalent circuit of the signal source is shown in Fig. 9. If the frequency of the signal source is 40 kHz , determine:

- the potential difference across the coil, and
- the power dissipated in the coil.

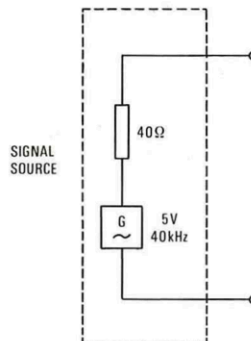


Fig. 9

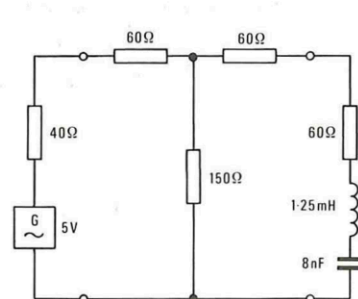
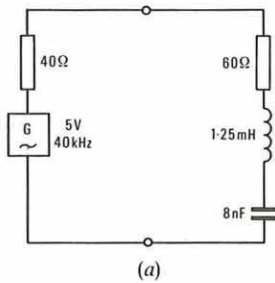


Fig. 10

(b) A T attenuator is introduced into the circuit as shown in Fig. 10. If the frequency of the signal source is adjusted for resonance in the series circuit, calculate the potential difference across the capacitor.

A11 (a) The complete circuit for the initial condition is shown in sketch (a).



(a)

(i) The total resistance, $R_t = 40 + 60 = 100 \Omega$.
At frequency (f) of 40 kHz, the inductive reactance of the coil, X_L , is given by

$$X_L = 2\pi fL = 2\pi \times 40 \times 10^3 \times 1.25 \times 10^{-3} = 314.2 \Omega$$

The reactance of the capacitor, X_C , is given by

$$X_C = \frac{1}{2\pi fC} = \frac{1}{2\pi \times 40 \times 10^3 \times 8 \times 10^{-9}} = 497.4 \Omega$$

The total impedance, Z , is given by

$$Z = \sqrt{R_t^2 + (X_L - X_C)^2} = \sqrt{100^2 + (314.2 - 497.4)^2} = 208.7 \Omega$$

The current,

$$I = \frac{\text{voltage}}{Z} = \frac{5}{208.7} \text{ A} = 23.96 \text{ mA}$$

The impedance of the coil, Z_L , is given by

$$Z_L = \sqrt{R^2 + X_L^2} = \sqrt{60^2 + 314.2^2} = 319.9 \Omega$$

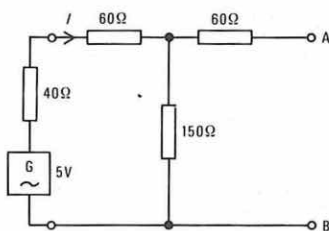
Therefore, the potential difference across the coil

$$= IZ_L = 23.96 \times 10^{-3} \times 319.9 = 7.66 \text{ V}$$

(ii) The power dissipated in the coil

$$= I^2 R = (23.96 \times 10^{-3})^2 \times 60 \text{ W} = 34.44 \text{ mW}$$

(b) The circuit shown in Fig. 10 can be simplified by using Thévenin's theorem. Consider only the attenuator and the signal source as shown in sketch (b).



(b)

$$I = \frac{5}{40 + 60 + 150} = 20 \text{ mA}$$

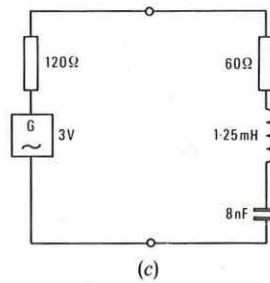
The potential difference across points A and B is given by

$$V_{AB} = I \times 150 = 20 \times 10^{-3} \times 150 = 3 \text{ V}$$

If the signal source is replaced by its internal impedance of 40 Ω , the resistance across points A and B is given by

$$\begin{aligned} R_{AB} &= 60 + \frac{(60 + 40) \times 150}{(60 + 40) + 150} \\ &= 60 + 60, \\ &= 120 \Omega \end{aligned}$$

The complete circuit thus simplifies to that shown in sketch (c).



(c)

If R_{t2} is the total resistance in this circuit, the Q factor of the complete circuit is given by

$$\begin{aligned} Q &= \frac{1}{R_{t2}} \sqrt{\frac{L}{C}}, \\ &= \frac{1}{(120 + 60)} \sqrt{\frac{1.25 \times 10^{-3}}{8 \times 10^{-9}}}, \\ &= 2.196 \end{aligned}$$

At resonance, the potential difference, V_C , across the capacitor is given by

$$V_C = QV_s,$$

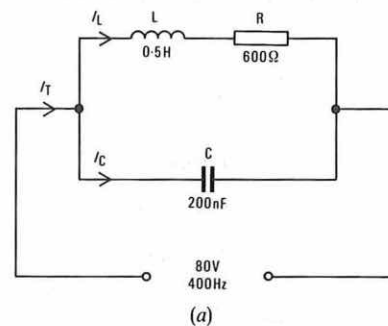
where V_s is the signal-source voltage of the simplified circuit.

$$\therefore V_C = 2.196 \times 3 = 6.59 \text{ V}$$

Q12 A coil having an inductance of 0.5 H and a resistance of 600 Ω is connected in parallel with a 200 nF capacitor across an 80 V 400 Hz supply. Calculate

- the impedance, and
- the power factor of the parallel combination.

A12 The complete circuit is shown in sketch (a).



(a)

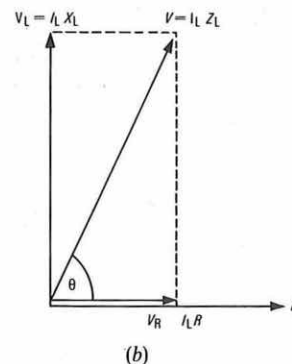
(a) The inductive reactance of the coil, X_L , at frequency f is given by

$$X_L = 2\pi fL = 2\pi \times 400 \times 0.5 = 1256.6 \Omega$$

The impedance of the coil, Z_L , is given by

$$Z_L = \sqrt{R^2 + X_L^2} = \sqrt{600^2 + 1256.6^2} = 1392.5 \Omega$$

The phasor diagram for the coil is shown in sketch (b).



(b)

$$I_L = \frac{V}{Z_L} = \frac{80}{1392.5} \text{ A} = 57.45 \text{ mA.}$$

$$\tan \theta = \frac{X_L}{R} = \frac{1256.6}{600}.$$

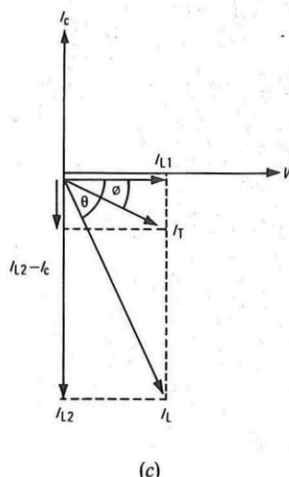
$$\therefore \theta = 64.48^\circ.$$

The reactance of the capacitor, X_c , is given by

$$X_c = \frac{1}{2\pi f c} = \frac{1}{2\pi \times 400 \times 200 \times 10^{-9}} = 1989.4 \Omega.$$

$$I_c = \frac{V}{X_c} = \frac{80}{1989.4} \text{ A} = 40.21 \text{ mA.}$$

The complete phasor diagram is shown in sketch (c).



Resolving I_L into in-phase (I_{L1}) and quadrature (I_{L2}) components gives

$$\cos \theta = \frac{I_{L1}}{I_L}.$$

$$\begin{aligned} \therefore I_{L1} &= I_L \cos \theta, \\ &= 57.45 \times \cos 64.48^\circ, \\ &= 24.75 \text{ mA.} \end{aligned}$$

$$\begin{aligned} \sin \theta &= \frac{I_{L2}}{I_L}, \\ \therefore I_{L2} &= I_L \sin \theta, \\ &= 57.45 \times \sin 64.48^\circ, \\ &= 51.84 \text{ mA} \end{aligned}$$

The supply current, I_T , is given by

$$\begin{aligned} I_T^2 &= I_{L1}^2 + (I_{L2} - I_C)^2, \\ \therefore I_T &= \sqrt{I_{L1}^2 + (I_{L2} - I_C)^2}, \\ &= \sqrt{24.75^2 + (51.84 - 40.21)^2}, \\ &= 27.35 \text{ mA.} \end{aligned}$$

The total impedance

$$= \frac{V}{I_T} = \frac{80}{27.35 \times 10^{-3}} = 2925 \Omega.$$

(b) The power factor

$$= \cos \phi = \frac{I_{L1}}{I_T} = \frac{24.75 \times 10^{-3}}{27.35 \times 10^{-3}} = 0.905.$$

Q13 A coil having an inductance of 2.5 H is connected in parallel with a 32 Ω resistor across a 24 V DC supply, as shown in Fig. 11. When switch S is closed, the current through the coil rises to a steady value of 3 A.

(a) Calculate, at the instant that switch S is opened

- the initial rate of change of current flowing through the coil, and
- the EMF induced in the coil.

(b) Determine the time which elapses from after switch S is opened until the potential difference across the coil reduces to 20 V.

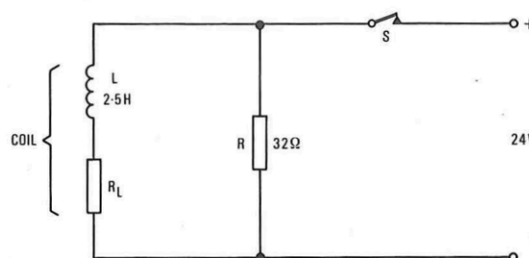


Fig. 11

A13 (a) (i) The steady value of current flowing through the coil, I_L , is determined by the resistance of the coil, R_L .

$$R_L = \frac{V}{I_L} = \frac{24}{3} = 8 \Omega.$$

The initial rate of change of current is $-I_L/T$ A/s, where T is the time constant of the current decay circuit. If R_T is the total resistance in the circuit,

$$T = \frac{L}{R_T} = \frac{2.5}{(8 + 32)} \text{ s} = \frac{2.5}{40} \text{ s} = 62.5 \text{ ms.}$$

Therefore, the initial rate of change of current

$$= -\frac{3}{62.5 \times 10^{-3}} = -48 \text{ A/s.}$$

(ii) The induced EMF, e , is given by

$$e = -L \frac{di}{dt},$$

where $\frac{di}{dt}$ is the rate of change of current.

At the instant switch S is opened,

$$e = -2.5 \times (-48) = 120 \text{ V.}$$

(b) The potential difference across the coil is equal to the potential difference across resistor R (v_R). When the potential difference across the coil has fallen to 20 V, the current flowing through the coil at this instant, i_L , is given by

$$i_L = \frac{v_R}{R} = \frac{20}{32} = 0.625 \text{ A.}$$

The current flowing through the coil at the instant switch S is opened is 3 A. The time taken (t) for the current to reduce to 0.625 A can be determined by using the following relationship:

$$i_L = I_L e^{-(Rt/L)} = I_L e^{-(t/T)}.$$

But, $T = 62.5 \text{ ms}$ (see part (a)(i)).

$$\therefore 0.625 = 3 e^{-(t/(62.5 \times 10^{-3}))} = 3 e^{-16t}.$$

$$\therefore e^{-16t} = \frac{0.625}{3}.$$

$$e^{16t} = \frac{3}{0.625} = 4.8.$$

$$\therefore 16t = \log_e 4.8 = 1.5686.$$

$$\therefore t = 98 \text{ ms.}$$

Questions and answers contributed by C. Wright